Rotation Group Bias in Smoking Prevalence Estimates Using TUS-CPS

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Abstract

This paper examined if smoking prevalence estimates based on the Tobacco Use Supplement to the Current Population Survey (TUS-CPS) suffer from rotation group bias due to panel attrition and panel conditioning. The TUS-CPS has been administered as part of the Current Population Survey (CPS), which has eight rotation groups of households in each month that are repeatedly interviewed based on a sample rotation scheme. Previous research has found that even though all eight rotation groups in the CPS are independent random samples of the population, some estimates, such as unemployment rates, tend to be significantly higher in the first rotation group than among other rotation groups. The multivariate probit regression results of this paper showed that although panel attrition is prevalent in all years of the TUS-CPS, for the six waves of TUS-CPS before 2003 there is no evidence that smoking prevalence estimates were significantly affected by the rotation scheme of the CPS. For the three waves of TUS-CPS since 2003, however, the results showed that smoking prevalence has been underestimated due to panel attrition and panel conditioning. It appears that rotation group bias in these waves was caused by the substantially increased number of additional questions smokers had to answer.

Keywords: rotation group bias, panel attrition, panel conditioning

1. Introduction

The adverse health effects from smoking caused more than 443,000 deaths, or nearly one of every five deaths, each year from 2000 to 2004 in the United States (Centers for Disease Control and Prevention 2008; National Center for Health Statistics 2007). In an effort to curtail this public health problem, decreasing the prevalence of cigarette smoking among adults to less than 12% has been one of the national health objectives for 2020 (U.S. Department of Health and Human Services 2013). To assess progress toward this objective, it is essential to precisely measure current smoking prevalence in the U.S. adult population.

One survey often used to provide such estimates is the Tobacco Use Supplement to the Current Population Survey (TUS-CPS). The Current Population Survey (CPS) is a monthly labor force survey conducted by the U.S. Census Bureau for the Bureau of Labor Statistics and is the source of official government statistics on employment and unemployment. The TUS-CPS, sponsored by the National Cancer Institute, is a survey of tobacco use that has been administered as part of the CPS in select months since 1992. Because it is based on a large, nationally representative sample of the CPS—individuals living in approximately 56,000 households, selected on the basis of area of residence across the country—the TUS-CPS has also been extensively used in tobacco research for small geographic regions, such as states (Biener et al. 2004; Shopland et al. 1996), and small groups, such as those defined by immigrant status, employment status, age, education, and race/ethnicity (Acevedo-Garcia et al. 2005; Baluja et al. 2003; Fagan et al. 2007; Green et al. 2007; Shavers et al. 2005).

The CPS is designed so that each household whose address is selected for the sample is repeatedly interviewed following a 4–8–4 sample rotation scheme: the household is interviewed for 4 consecutive months, not surveyed for 8 consecutive months, and then re-interviewed for 4 consecutive months before being finally dropped from the survey. This rotation scheme was introduced as a way to reduce response burden and also as a compromise between a permanent sample (from which a high response rate would be difficult to maintain) and a completely new sample each month (which results in more variable estimates of change) (U.S. Census Bureau 2006). Each month a new group of households enters the sample for the first time and another group of households retires from the sample

permanently. In any particular month, as a result, there are eight groups of households and the number of times each household's address is in the sample varies from 1 (Rotation Group 1) to 8 (Rotation Group 8). Typically, most CPS interviews for the first and the fifth rotation groups are conducted in person because the CPS sample is strictly a sample of addresses and the U.S. Census Bureau needs to confirm that the respondents are, in fact, residing in the sample household. However, if the respondent requests during the initial personal contact, telephone interviews are conducted even for these rotation groups. Most interviews for the remaining rotation groups are conducted over the telephone, with the approval of the respondent. Telephone interviewing is generally preferred because it is much more time and cost efficient. In the interests of timeliness and efficiency, the CPS also allows proxy responses: any knowledgeable adult household member can be the respondent for other household members and the respondent can change from interview to interview. Yet the majority of the CPS data is collected by self-response (U.S. Census Bureau 2006).

Although the TUS-CPS has been regarded as a "gold standard" for state estimates (Biener et al. 2004), its national-level estimates for smoking prevalence have been consistently lower than those from the National Health Interview Survey (NHIS), another data set commonly used to measure smoking prevalence in the U.S. adult population (Rodu and Cole 2009). For example, the national-level estimate for smoking prevalence from the 2011 NHIS was 19%, whereas the estimate from self-responses of the 2010–11 TUS-CPS was 16.1% (Centers for Disease Control and Prevention 2012; National Cancer Institute 2013). The NHIS, conducted by the National Center for Health Statistics, an arm of the Centers for Disease Control and Prevention, is based on a cross-sectional representative sample of the civilian noninstitutionalized population of the U.S. Unlike the TUS-CPS, the NHIS does not rely on a sample rotation scheme and collects all data through personal interviews. In addition, proxy responses are rarely allowed in the NHIS. Considering these differences in survey methodologies between the two surveys, it is natural to investigate how they affect the estimates of smoking prevalence in the TUS-CPS.

The effects of survey mode (telephone or in-person) and respondent type (self or proxy) on the estimates of smoking prevalence have received extensive attention in the literature (Baron-Epel et al. 2004; Beland and St-Pierre 2008; Caraballo et al. 2001; Donovan et al. 1997; Gilpin et al. 1994; Harakeh et al. 2006; Hyland et al. 1997; Navarro 1999; Simile et al. 2006). Recently Soulakova et al. (2009) investigated whether survey mode and respondent type affect the current smoking prevalence estimates in the 1992 through 2003 TUS-CPS. After controlling for various sociodemographic characteristics, they found that the smoking prevalence obtained from proxy-responses is lower than that obtained from self-responses. They also concluded that the smoking prevalence obtained from telephone responses underestimates the current smoking rate by 3 percentage points.

One important survey methodological factor that Soulakova et al. (2009) failed to examine is the sample rotation scheme of the CPS and its effect on smoking prevalence estimates in the TUS-CPS. Because each rotation group in the CPS is an independent random sample of the population, it is possible to get eight separate estimates of the population characteristic of interest for a given month, and these estimates from different rotation groups supposedly should not differ systematically. However, some estimates, such as unemployment rates, tend to be significantly higher in the first rotation group than among other rotation groups (Bailar 1975; Brooks and Bailar 1978; Hansen et al. 1955; McCarthy 1978; Shack-Marquez 1986; Solon 1986; U.S. Census Bureau 2006; Williams and Mallows 1970). Such differences in estimates are called *rotation group bias* or *time-in-sample bias*. Some factors have been suggested for why responses may vary systematically with time in the sample (McCarthy 1978): conditioning of respondents or interviewers by repeated interviews; differences in the lengths and contents of the questionnaire among rotation groups (the first interview is longer than others because demographic information about all members of the household has to be obtained); differences in the mode of interview; differences in the respondents for the household; and differences in the characteristics of nonrespondents among rotation groups. It has also been shown that the estimators using the full sample are biased unless these systematic biases across rotation groups cancel each other out (Bailar 1975; Solon 1986).

Given that the TUS-CPS is based on the CPS, it is natural to suspect that smoking prevalence estimates based on the TUS-CPS will exhibit rotation group bias. Among the various suggested factors for rotation group bias, this paper focuses on differences in the characteristics—in particular, smoking status—of nonrespondents among rotation groups (panel attrition) and panel conditioning. Previous research has shown that tobacco users are more likely to attrite in longitudinal surveys (Cunradi et al. 2005; Gray et al. 1996; Young et al. 2006). Using two rounds of a survey on health and lifestyles among adults in Great Britain in 1984–85 and 1991–92, Gray et al. (1996) found that regular smokers were more likely to attrite, partly due to their higher mortality. Using two rounds of survey data, in

1998 and 2000, from a cohort of young adults recruited for the U.S. Navy, Cunradi et al. (2005) also found that baseline tobacco users were more likely to be attritors than nonusers, even after controlling for other factors, including education and religious affiliation. Finally, using data from three age cohorts (18–23 years, 45–50 years, and 70–75 years) of the Australian Longitudinal Study on Women's Health, initially collected in 1996 with a follow-up 2–4 years later, Young et al. (2006) found that in all age cohorts, women who were current smokers were more likely to become nonrespondents, even after health status and other socioeconomic factors were controlled for.

One explanation for the higher attrition of smokers is because smokers are more likely to develop health problems that would decrease their ability to respond to follow-up surveys. Another explanation is that some characteristics associated with smoking make smokers less willing to participate in survey follow-up than nonsmokers. In fact, smokers are less likely to use a seat belt, brush or floss their teeth, and do physical exercise than nonsmokers (Hersch 1996). Also smokers are more impulsive than nonsmokers in that they choose small but immediate rewards over large but delayed rewards (Bickel et al. 1999; Khwaja et al. 2006; Lahiri and Song 2000; Odum et al. 2002; Reynolds et al. 2004). Furthermore, smokers have substantially less education (Levine et al. 1997), lower wages (Grafova and Stafford 2009; Munasinghe and Sicherman 2006), are less likely to vote at election time (Denny and Doyle 2007; Keller et al. 2002) and spend more time on activities that provide immediate gratification, such as watching television, but less time on activities that provide long-term returns, such as exercising and education, than nonsmokers (Song 2011). Regardless of the reasons, the higher attrition of smokers in panel surveys found in previous literature suggests that the successive rotation groups in the TUS-CPS could be subject to the same problem. Then, estimates using all rotation groups in the TUS-CPS are likely to underestimate "true" smoking prevalence.

Recently Halpern-Manners and Warren (2012) showed evidence for panel conditioning effects in the CPS.[1] To identify panel conditioning effects in the basic CPS, they examined unemployment rates comparing people who differ only with respect to whether they were interviewed for the first time or second time in the CPS, by only using individuals in the first and second rotation groups in the same CPS month, who were household heads, self-respondents, and matched across their first and second months in sample. They found that even in this restricted group, free of panel attrition, unemployment rates were consistently lower in the second rotation group because in an effort to minimize their survey burden after participating in the CPS for the first time, some respondents changed their labor force status from "unemployed" to "out of labor force." As a result, estimates of unemployment rates based on all rotation groups in the basic monthly CPS are downwardly biased. They also noted that panel conditioning effects are frequently observed when survey waves are separated by 1 month or less, such as the basic monthly CPS survey, but fewer panel conditioning effects are expected when surveys are separated by longer periods of time. Except for a few months, respondents in general participate in the TUS-CPS only once. However, they are still part of the rotation scheme of the CPS and thus may change their responses to the TUS-CPS to minimize their burden after initial participation in the CPS. Then, estimates using all rotation groups in the TUS-CPS are likely to underestimate "true" smoking prevalence.

2. Descriptive Analysis of Rotation Group Bias

The national level estimates of smoking prevalence for the population 18 years and older by the National Cancer Institute are based on three TUS-CPS data sets pooled from adjacent periods (National Cancer Institute 2013). So I first estimated smoking prevalence by rotation group for the following years of TUS-CPS using pooled data in adjacent periods: 1992– 93 (September 1992, January 1993, and May 1993), 1995–96 (September 1995, January 1996, and May 1996), 1998–99 (September 1998, January 1999, and May 1999), 2000 (January 2000 and May 2000), 2001–02 (June 2001, November 2001, and February 2002), 2003 (February 2003, June 2003, and November 2003), 2006–07 (May 2006, August 2006, and January 2007), and 2010–11 (May 2010, August 2010, and January 2011). (Only two TUS-CPS data sets were collected in 2000.) All estimates are weighted using the TUS-CPS nonresponse weights (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method in Stata.

Table 1 provides estimates of current smokers for each year of TUS-CPS by rotation group. It shows evidence that estimates of current smokers based on the TUS-CPS vary by rotation group and the estimate for the first rotation group is higher than the estimates for other rotation groups. This is clearly demonstrated by means of a rotation

[1] See Warren and Halpern-Manners (2012) for a general overview of panel conditioning in longitudinal data.

group index: the ratio of the estimate based on a particular rotation group to the average estimate over all eight rotation groups, multiplied by 100 (Bailar 1975; U.S. Census Bureau 2006). If an equal percentage of current smokers are present in each rotation group, the index for each rotation group would be 100. In Table 1, the index of 105.39 for the first rotation group in the 1992–93 TUS-CPS indicated that the rotation group in the sample for the first time gave an estimate 5.39% higher than the average for all rotation groups. Figure 1, which graphically presents these rotation group indices, illustrates that for all years of TUS-CPS, estimates of smoking prevalence are higher for those in their first month in the sample than for TUS-CPS respondents as a whole. Furthermore, it is also clear from Figure 1 that the difference in smoking prevalence between the first rotation group and the overall group became substantially larger since 2003. Between 1992–2002, the rotation group indices for respondents in their first month in the sample are about 105, but between 2003–2011, they are about 110.

3. Regression Analysis of Rotation Group Bias

Significant variations in rotation group indices found in the above analysis, however, do not necessarily imply that there are systematic biases in estimates of smoking prevalence across rotation groups. The distribution of other covariates associated with smoking status, such as age, gender, race/ethnicity, and education of the respondents, can certainly vary across rotation groups. Furthermore, factors—such as the mode of interview and respondents for the household—vary across rotation groups (McCarthy 1978). To control for all these differences, I conducted multivariate probit analysis for each period. The dependent variable was a dummy variable for current smokers. In addition to a dummy for the first rotation group, the following variables that are typically controlled for as determinants of smoking were included as the independent variables: three dummies for age categories (18 to 24, 25 to 44, 45 to 64; the reference group is age 65 or older); a female dummy; five dummies for race/ethnicity (Black, Hispanic, American Indian/Alaskan Native, Asian/Pacific Islander, and other; the reference group is White); three dummies for education (high school, some college, and college or more; the reference group is less than high school); two dummies for employment status (unemployed and not in labor force; the reference group is employed); three dummies for marital status (married, widowed, and divorced/separated; the reference group is never married); dummies for family income levels, including family income missing; a dummy for home owner[2]; two dummies for metropolitan areas (non metropolitan area and not identified; the reference group is metropolitan area); three region dummies; dummies for TUS-CPS month in each period; a dummy for self-response (the reference group is proxy response); and two dummies for survey mode (personal and unknown; the reference group is telephone interview).[3] The marginal effects of the dummy for the first rotation group will show the magnitude of rotation group bias.

The probit marginal effects of the first rotation group for each period are presented in Table 2. For comparison, Panel A of Table 2 reports the results where the only control variable is the dummy for the first rotation group, whereas Panel B of Table 2 reports the probit marginal effects of the model that includes the above-mentioned full control variables. Similar to the findings in Table 1, in Panel A of Table 2 the prevalence estimates of smoking are 0.9 to 2.1 percentage points higher for the first rotation group than for Rotation Groups 2 through 8. And the differences became larger since 2003. Considering that estimates of smoking prevalence—the means of the dependent variable reported in Table 2—have been monotonically decreasing between 1992 and 2011, the magnitudes of the difference between the first rotation group and the rotation groups 2 through 8 as a fraction of the estimates of smoking prevalence have also become larger in recent years. In Panel B of Table 2, when the differences in characteristics of the respondents, the modes of interview and respondent types between the first rotation group and other rotation groups are controlled for, the gaps in smoking prevalence became smaller for all periods but still remained statistically significant for the years 2003, 2006–07, and 2010–11. In sum, the findings in Panels A and B of Table 2 indicated that for the years 1992–93, 1995–96, 1998–99, 2000, and 2001–02, rotation group bias observed in Panel A was due to the differences in characteristics of the respondents, the modes of interview and respondent types between the first rotation group and other rotation groups. In contrast, for the years 2003, 2006–07, and 2010–11, these differences do not fully explain the difference between the first rotation group and other rotation groups. If only Rotation Group 1 was used, rather than using all rotation groups, to estimate smoking prevalence, the estimates would have been higher by 1.6 to 1.8 percentage points, about 3.6 to 3.9 million more smokers, for the years 2003, 2006–07, and 2010–11.

[2] Balabanova et al. (1998) and Laaksonen et al. (2005) showed that home ownership is negatively correlated with smoking.

[3] For 1992–93 TUS-CPS, a dummy for unknown respondent type is also included.

4. Changes in the TUS-CPS

Given the findings in the previous section that rotation group bias is still observed for the years 2003, 2006–07, and 2010–11, even after controlling for other covariates, but not for the years 1992–93, 1995–96, 1998–99, 2000, and 2001–02, it is worthwhile to investigate if any of the changes over time in the TUS-CPS relate to that pattern. According to the National Cancer Institute (2013), all TUS-CPS contain generally the same information, covering current cigarette smoking status and amount smoked; smoking history, quit attempts, and intention to quit; medical/dental advice to quit; cigar, pipe, and smokeless tobacco use; workplace and home smoking restrictions; and attitudes toward smoke-free policies in public places. Since 2003, as shown in Table 3, the following information was also collected from smokers: use of menthol cigarettes; level of nicotine dependence; cost of cigarettes and purchase location; and harm reduction and other emerging products. As a result, the number of questions in the TUS-CPS increased substantially since 2003 and may have increased the burden on respondents, in particular those responding as smokers. For example, Table 3 shows that before 2003, the number of variables listed in the TUS-CPS codebook did not change noticeably, staying between 69 and 85, except 27 for the 2000 TUS-CPS when an abbreviated version of the TUS-CPS was implemented. But since 2003 the number of variables listed in the TUS-CPS codebook increased almost two- to four-fold, reaching 240 in 2003, 168 in 2006–07, and 323 in 2010–11. Although the last column of Table 3 shows that the person nonresponse rates to the TUS-CPS have not fallen significantly since 2003, these changes in survey questions since 2003 may have put more burden on individuals who respond as smokers and may have affected their behavior in participating in the TUS-CPS, through panel attrition and panel conditioning. And as a result, they may have caused rotation group bias for the years 2003, 2006–07, and 2010–11 observed in the previous section.

5. Panel Attrition in the TUS-CPS

To examine if rotation group bias is due to higher attrition rates of smokers in the successive rotation groups in the CPS, using the rotation scheme of the CPS, I matched Rotation Group 1 from all the TUS-CPS to the subsequent CPS and tested if current smokers are less likely to be interviewed in the subsequent rotation groups in the CPS. For example, Rotation Group 1 from the January 2007 TUS-CPS can be matched to Rotation Group 2 in the February 2007 CPS, Rotation Group 3 in the March 2007 CPS, and so on. Similar to the matching process used in Song (2011), I followed the guidelines from the U.S. Bureau of Labor Statistics (2010) and linked observations from Rotation Group 1 from the January 2007 TUS-CPS to Rotation Group 2 in the February 2007 CPS by using a set of household and individual identification variables.[4] Although these identification variables produce unique matches, one also needs to check sex, race, and age because the CPS is a sample of housing addresses and not a sample of individuals. Successful matches should have the same values for sex and race, and acceptable ranges of age difference between the two surveys (Madrian and Lefgren 2000).[5] By using the first rotation groups in each of the TUS-CPS, I examined whether the rate of successful match varied by smoking status. To control for the differences in other characteristics that may affect matching, I also conducted a multivariate probit analysis of matching. A set of control variables similar to those used in Panel B of Table 2 plus a dummy for availability of a telephone in the house are included as independent variables (Abraham et al. 2006).

Table 4 reports the marginal effects of smoking in these Probit regressions. Consistent with the findings in the previous literature (Cunradi et al. 2005; Gray et al. 1996; Young et al. 2006), smokers are less likely to be matched to the subsequent CPS in almost all years. For example, the marginal effect of -0.025 in the first row of column 7 indicates that smokers in Rotation Group 1 from the 1992–93 TUS-CPS (September 1992, January 1993, and May 1993) are, on average, 2.5 percentage points less likely to be interviewed than nonsmokers 15 months later as Rotation Group 8 in the December 1993, April 1994, and August 1994 CPS, even after controlling for other covariates. Although the evidence of higher attrition rates for smokers in the extant literature is based on panel data at least 2 years apart, the results in Column 1 of Table 4 indicate that smokers in Rotation Group 1 in the 2006–07

[4] For the files matched to the 1992–93 TUS-CPS, the following variables are used in linking: HRHHID, HUHHNUM, and PULINENO. For the files matched to the 1995–96, 1998–99, 2000, 2001–02, and 2003 TUS-CPS, the following variables are used in linking: HRHHID, HRSERSUF, HUHHNUM, HRSAMPLE, and PULINENO. For the files matched to the 2006–07 and 2010–11 TUS-CPS, the following variables are used in linking: HRHHID, HRHHID2, and PULINENO.

[5] Due to the changes, race categories beginning in 2003 are not comparable to race categories before 2003. Therefore, in linking the 2001–02 TUS-CPS to the 2003 CPS, race was not used in determining successful matches.

TUS-CPS are significantly less likely to be interviewed than nonsmokers, even in the CPS that is only 1 month after the TUS-CPS.

Although the results in Table 4 provide evidence that smokers are more likely to attrite in subsequent rotation groups in the CPS, they are not providing convincing evidence that the pattern of rotation group bias observed in Table 2 is due to panel attrition. First, although Panel B of Table 2 shows significant marginal effects of Rotation Group 1 only for the years 2003, 2006–07, and 2010–11, Table 4 shows smokers are significantly more likely to attrite in the subsequent rotation groups in all years. Furthermore, the magnitudes of the marginal effects observed in Table 4 are too small to generate the magnitudes of the marginal effects of Rotation Group 1 of 0.9 to 1.6 percentage points, compared with rotation groups 2 through 8, observed in Panel B of Table 2 for the years 2003, 2006–07, and 2010–11. For example, with the smoking prevalence estimate of 20% in Rotation Group 1, the difference in attrition rates of 3 percentage points between smokers and nonsmokers[6] would generate a difference less than 0.5 percentage points in smoking prevalence estimates between Rotation Group 1 and other rotation groups.[7] Finally, Table 4 only shows that smokers are more likely to attrite in subsequent rotation groups in the *CPS*, not in the *TUS-CPS*. Because the TUS-CPS is a supplement to the CPS, some of those who responded to the basic CPS questionnaires did not respond to the TUS-CPS questionnaires. For example, the household nonresponse rates for May and August 2006, and January 2007 on the basic CPS ranged from 7.6 to 9.1%, whereas the person nonresponse rates for the May and August 2006, and January 2007 TUS-CPS range from 14.8 to 19.3% (U.S. Census Bureau 2008). Then, rotation group bias in the TUS-CPS may be observed not because current smokers are less likely to participate in the basic CPS but because they are less likely to respond to the TUS-CPS. To examine this possibility, I matched two TUS-CPS data a year apart and examined whether the probability of a successful match varied by smoking status. There are three pairs of TUS-CPS data that can be matched. Rotation Groups 1, 2, 3, and 4 from the January and May 1999 TUS-CPS can be matched to Rotation Groups 5, 6, 7, and 8 from the January and May 2000 TUS-CPS; and Rotation Groups 1, 2, and 3 from the February 2002 TUS-CPS can be matched to Rotation Groups 5, 6, and 7 from the February 2003 TUS-CPS (Rotation Group 4 was interviewed for the basic CPS but not for the Tobacco Use Supplement in February 2002). For comparability to Table 4, I only examined Rotation Group 1 from these TUS-CPS. Following the same matching procedure used for matching the TUS-CPS to the basic CPS, I matched Rotation Group 1 from the January, May 1999 and February 2002 TUS-CPS to Rotation Group 5 in the January, May 2000 and February 2003 TUS-CPS and ran a multivariate probit analysis of matching, including the same set of control variables used in Table 4.

Table 5 reports the marginal effects of smoking in these probit regressions. The first row of Table 5 shows that in matching Rotation Group 1 in the January and May 1999 TUS-CPS to Rotation Group 5 in the January and May 2000 *Basic CPS*, smokers are 3.09 percentage points less likely to be matched than nonsmokers. And in Column 2 of Table 5 the magnitude of the negative marginal effect of smoking does not change substantially in matching Rotation Group 1 in the January and May 1999 TUS-CPS to Rotation Group 5 in the January and May 2000 *TUS-CPS*. In the second row of Table 5, the magnitude of the negative marginal effect of smoking becomes substantially larger in matching Rotation Group 1 in the February 2002 TUS-CPS to Rotation Group 5 in the February 2003 CPS than those observed in row 1 of Table 5. Furthermore, the magnitude of the negative marginal effect of smoking becomes even larger in matching Rotation Group 1 in the February 2002 TUS-CPS to Rotation Group 5 in the February 2003 TUS-CPS than in matching to the February 2003 Basic CPS. Therefore, the results in Table 5 provide evidence that the level of higher attrition rates of smokers in the successive rotation group for the 1999 TUS-CPS is no less severe in matching to TUS-CPS than in matching to the Basic CPS. Furthermore, in matching to the February 2003 TUS-CPS, where the burden of survey increased dramatically, the attrition rate for smokers seems to have increased substantially than in matching to the February 2003 Basic CPS, which is already higher than the attrition rate observed in matching Rotation Group 1 in the January and May 1999 TUS-CPS to Rotation Group 5 in the January and May 2000 *Basic CPS*. If the same level of substantially increased attrition rates for

[6] Because the marginal effects of Rotation Group 1 observed in Panel B of Table 2 are compared with rotation groups 2 through 8, I first calculated the simple average of the marginal effects of smoking in Table 4 for each year over columns 1 through 7. The averages, ranging from -0.0103 in 2000 to -0.0284 in 2010-11, are well under the difference in attrition rates of 3 percentage points between smokers and nonsmokers used in this example.

[7] If 100% of the nonsmokers and 97% of the smokers from Rotation Group 1 are interviewed in the subsequent month, the percent of smokers in the subsequent month would be (20*0.97)*100/(20*0.97+80)=19.52, which is 0.48 percentage points less than 20. This number is invariant to overall follow-up interview rates.

smokers were continued in the years after 2003 because of the increased burden of survey in the TUS-CPS, the pattern of rotation group bias observed in Panel B of Table 2 could have resulted.

6. Panel Conditioning in the TUS-CPS

To examine if rotation group bias is due to panel conditioning in the successive rotation groups in the CPS, I first selected people who differ only with respect to whether they were interviewed for the first time or second time in the TUS-CPS or CPS, using a method similar to that used in Halpern-Manners and Warren (2012). For example, from Rotation Group 1 in the May 2006 TUS-CPS, only those matched to Rotation Group 2 in the June 2006 CPS were selected; from Rotation Group 2 in the May 2006 TUS-CPS, only those matched to Rotation Group 1 in the April 2006 CPS were selected. In the end, the resulting sample contains only those individuals from rotation groups 1 and 2 in the May 2006 TUS-CPS who were interviewed in two consecutive months and, as a result, any significant differences between these two groups of people would be evidence of panel conditioning.[8] Ideally, to remove the effect of panel attrition completely, one needs to match rotation groups from one TUS-CPS to another TUS-CPS. However, there are no TUS-CPS data that are 1 month apart. I used the Basic CPS in lieu of the TUS-CPS. If the attrition rate by smoking status between one set of TUS-CPS data and one set of CPS data is similar to that between two TUS-CPS data, this method is not going to be problematic in detecting evidence of panel conditioning. However, if the attrition rate for smokers is higher in matching to one set of TUS-CPS data than in matching to one set of CPS data (as shown in the second row of Table 5), Rotation Group 1 in a TUS-CPS, whose second interview is in the CPS, will have a higher proportion of smokers than Rotation Group 2, whose second interview is in the TUS-CPS, in the matched data. Therefore, a higher proportion of smokers among Rotation Group 1 than among Rotation Group 2 in this matched data would be evidence of panel conditioning or panel attrition.

I applied this procedure to each and every month of the TUS-CPS. Panel A of Table 6 shows the marginal effects of Rotation Group 1, relative to Rotation Group 2, in probit regression on current smoking with no other control variable in the matched data. Of the eight TUS-CPS data sets, six have positive and significant marginal effects for Rotation Group 1, suggesting that, as a result of panel conditioning (or panel attrition), those interviewed for the second time in the TUS-CPS may have lower rates of smoking prevalence than those interviewed for the first time. However, when the differences in other characteristics between Rotation Groups 1 and 2 are controlled for in Panel B of Table 6 by including the same set of control variables used in Panel B of Table 2, only the marginal effect of Rotation Group 1 in the 2003 TUS-CPS is positive and statistically significant.[9] In sum, the results in Panel B of Table 6 provide evidence of panel conditioning (or panel attrition) for 2003. And rotation group bias observed for 2003in Panel B of Table 2 is likely to be due to panel conditioning (or panel attrition).

7. Conclusions

The main goal of this paper is to examine if the sampling rotation scheme used in the CPS results in an underestimation of smoking prevalence in the TUS-CPS. The analysis reported in this paper showed that although panel attrition is prevalent in all years, for the six waves of TUS-CPS before 2003 there is no evidence that smoking prevalence estimates were significantly affected by the rotation scheme of the CPS. For the three waves of TUS-CPS since 2003, however, the results showed that smoking prevalence has been underestimated due to panel attrition and panel conditioning. It appears that rotation group bias in these waves was caused by the substantially increased number of additional questions smokers have to answer. Therefore, one way to reduce the effect of rotation group bias in the future waves of TUS-CPS would be to alleviate the burden on respondents by reducing the number of questions for smokers.

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[8] Another assumption in my analysis is that panel conditioning may arise from participating in the CPS and TUS-CPS in consecutive months. By participating in one basic CPS, respondents may learn that their responses may affect the number of additional questions they need to answer and in the end, the length of the interview. So in their second interview in the TUS-CPS, they may manipulate a survey instrument in an effort to minimize the length of the survey and their burden.

[9] In their analysis of panel conditioning, Halpern-Manners and Warren (2012) restricted their samples to individuals who were household heads, self-respondents, and matched across their first and second months in the sample. However, they did not control for differences in other characteristics, including the survey mode. Considering the changes between Panels A and B of Table 6, their results need to be reexamined with more control variables.

Finally, the problem of underestimating smoking prevalence due to the higher attrition of smokers in longitudinal data may not be limited to the TUS-CPS. It also broadly applies to any longitudinal survey data that have some measures of smoking, such as the Panel Study of Income Dynamics, National Longitudinal Study of Adolescent Health, Monitoring the Future, National Longitudinal Survey of Youth, International Tobacco Control Policy Evaluation Project, Health and Retirement Study, and the National Youth Smoking Cessation Survey. Therefore, along with survey mode and respondent type, researchers will need to consider the effect of different attrition by smoking status in estimating the prevalence of smoking using these longitudinal data.

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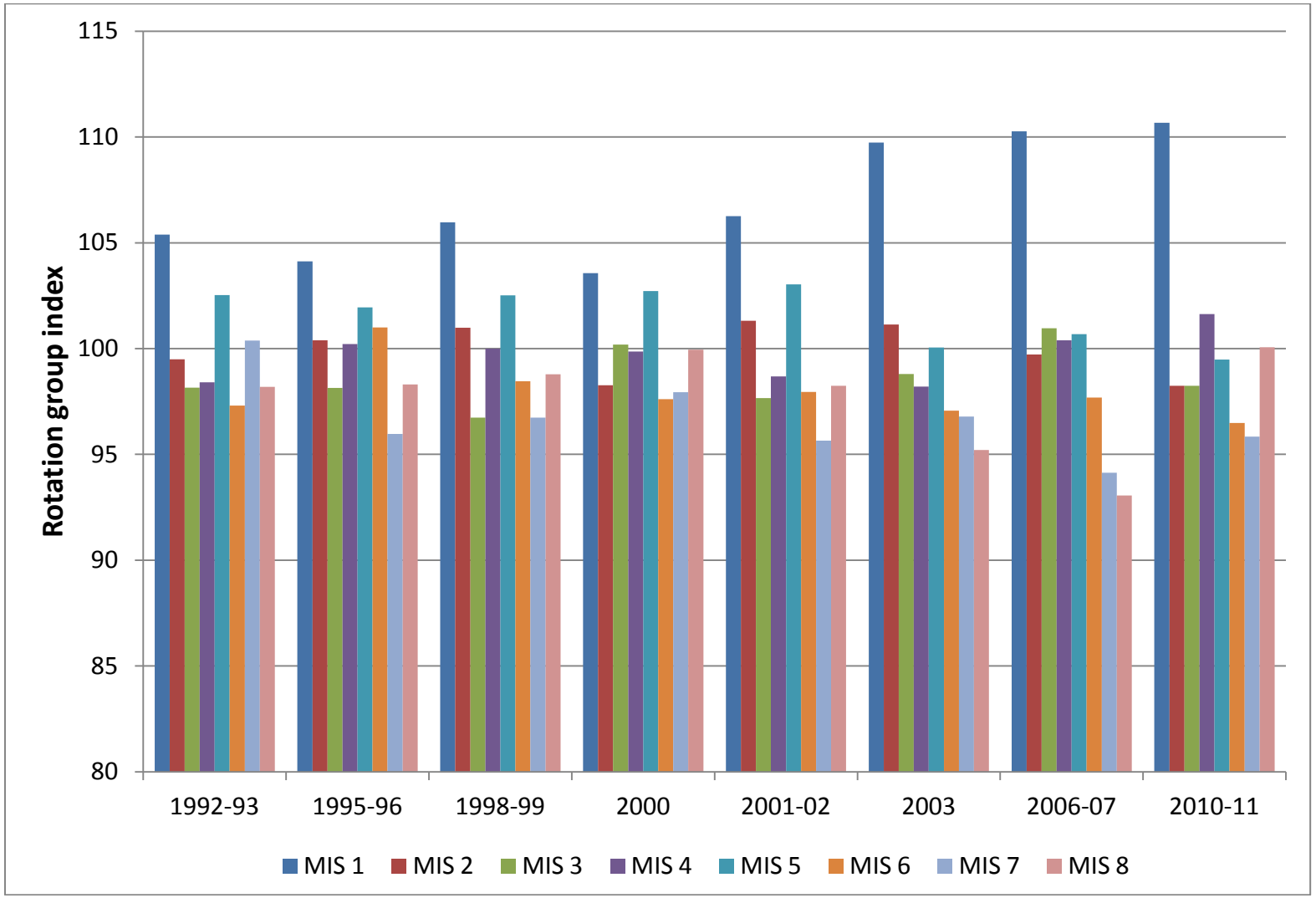
Table 1 Current Smokers: Percentage Estimates and Rotation Group Indices, U.S. Household Population, 18 Years and Over, 1992–2011 TUS-CPS

	Month in sample								Sample
	1	2	3	4	5	6	7	8	Size
1992–93 TUS-CPS									277,703
Percentage estimate	25.03	23.63	23.31	23.37	24.35	23.11	23.84	23.32	
	(0.38)	(0.4)	(0.39)	(0.33)	(0.3)	(0.37)	(0.34)	(0.35)	
Rotation group index	105.39	99.49	98.15	98.40	102.53	97.31	100.38	98.19	
	(1.60)	(1.68)	(1.64)	(1.39)	(1.26)	(1.56)	(1.43)	(1.47)	
1995–96 TUS-CPS									233,737
Percentage estimate	24.03	23.17	22.65	23.13	23.53	23.31	22.15	22.69	
	(0.36)	(0.36)	(0.35)	(0.35)	(0.36)	(0.36)	(0.34)	(0.36)	
Rotation group index	104.12	100.39	98.14	100.22	101.95	101.00	95.97	98.31	
	(1.56)	(1.56)	(1.52)	(1.52)	(1.56)	(1.56)	(1.47)	(1.56)	
1998–99 TUS-CPS									224,902
Percentage estimate	22.71	21.64	20.73	21.43	21.97	21.10	20.73	21.17	
	(0.34)	(0.32)	(0.34)	(0.34)	(0.35)	(0.32)	(0.35)	(0.37)	
Rotation group index	105.97	100.98	96.73	100.00	102.52	98.46	96.73	98.79	
	(1.59)	(1.49)	(1.59)	(1.59)	(1.63)	(1.49)	(1.63)	(1.73)	
2000 TUS-CPS									156,764
Percentage estimate	22.09	20.96	21.37	21.30	21.91	20.82	20.89	21.32	
	(0.40)	(0.45)	(0.41)	(0.38)	(0.41)	(0.34)	(0.41)	(0.43)	
Rotation group index	103.08	97.81	99.72	99.39	102.24	97.15	97.48	99.49	
	(1.87)	(2.10)	(1.91)	(1.77)	(1.91)	(1.59)	(1.91)	(2.01)	
2001–02 TUS-CPS									234,227
Percentage estimate	21.74	20.73	19.98	20.19	21.08	20.04	19.57	20.1	
	(0.35)	(0.34)	(0.29)	(0.4)	(0.31)	(0.35)	(0.33)	(0.43)	
Rotation group index	106.26	101.32	97.65	98.68	103.03	97.95	95.65	98.24	
	(1.71)	(1.66)	(1.42)	(1.96)	(1.52)	(1.71)	(1.61)	(2.10)	
2003 TUS-CPS									234,274
Percentage estimate	20.17	18.59	18.16	18.05	18.39	17.84	17.79	17.5	
	(0.29)	(0.34)	(0.3)	(0.38)	(0.3)	(0.28)	(0.34)	(0.4)	
Rotation group index	109.74	101.14	98.80	98.20	100.05	97.06	96.79	95.21	
	(1.58)	(1.85)	(1.63)	(2.07)	(1.63)	(1.52)	(1.85)	(2.18)	
2006–07 TUS-CPS									227,428
Percentage estimate	19.54	17.67	17.89	17.79	17.84	17.31	16.68	16.49	
	(0.31)	(0.29)	(0.32)	(0.38)	(0.33)	(0.32)	(0.31)	(0.34)	
Rotation group index	110.27	99.72	100.96	100.40	100.68	97.69	94.13	93.06	
	(1.75)	(1.64)	(1.81)	(2.14)	(1.86)	(1.81)	(1.75)	(1.92)	
2010–11 TUS-CPS									227,722
Percentage estimate	17	15.09	15.09	15.61	15.28	14.82	14.72	15.37	
	(0.31)	(0.32)	(0.27)	(0.34)	(0.28)	(0.3)	(0.28)	(0.35)	
Rotation group index	110.68	98.24	98.24	101.63	99.48	96.48	95.83	100.07	
	(2.02)	(2.08)	(1.76)	(2.21)	(1.82)	(1.95)	(1.82)	(2.28)	

Note: Standard errors are in parentheses. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method.

Figure 1 Rotation Group Indices for Current Smokers, 1992–2011 TUS-CPS



Note: MIS stands for Month In Sample.

Table 2 Marginal Effects of Rotation Group 1 in Probit Regression on Current Smokers, U.S. Household Population, 18 Years and Over, 1992–2011 TUS-CPS

Dependent variable: Current Smoker

Panel A No Control

	(1) 1992–93	(2) 1995–96	(3) 1998–99	(4) 2000	(5) 2001–02	(6) 2003	(7) 2006–07	(8) 2010–11
Rotation group 1	0.015***	0.011***	0.014***	0.009*	0.015***	0.020***	0.021***	0.019***
	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
Observations	277,703	233,737	224,902	156,764	234,227	234,274	227,428	227,722
Mean of the dependent variable	0.237	0.231	0.214	0.213	0.205	0.184	0.177	0.154

Panel B Full Control

	(1) 1992–93	(2) 1995–96	(3) 1998–99	(4) 2000	(5) 2001–02	(6) 2003	(7) 2006–07	(8) 2010–11
Rotation group 1	-0.001	-0.001	-0.000	-0.002	0.004	0.016***	0.011***	0.009***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Observations	277,703	233,737	224,902	156,764	234,227	234,274	227,428	227,722
Mean of the dependent variable	0.237	0.231	0.214	0.213	0.205	0.184	0.177	0.154
Mean of the dependent variable for rotation group 1	0.250	0.240	0.227	0.221	0.217	0.202	0.195	0.170
Difference	-0.013	-0.009	-0.013	-0.008	-0.012	-0.018	-0.018	-0.016

Note: Standard errors in parentheses. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
The following control variables are included in the results presented in Panel B: three dummies for age categories (18 to 24, 25 to 44, 45 to 64; the reference group is age 65 or older); a female dummy; five dummies for race/ethnicity (Black, Hispanic, American Indian/Alaskan Native, Asian/Pacific Islander, and other; the reference group is White); three dummies for education (high school, some college, and college or more; the reference group is less than high school); two dummies for employment status (unemployed and not in labor force; the reference group is employed); three dummies for marital status (married, widowed, and divorced/separated; the reference group is never married); dummies for family income levels, including family income missing; a dummy for home owner; two dummies for metropolitan areas (non metropolitan area and not identified; the reference group is metropolitan area); three region dummies; dummies for TUS-CPS month in each period; a dummy for self-response (the reference group is proxy response); and a dummy for personal interview (the reference group is telephone interview).

Table 3 Number of Variables and Changes in the TUS-CPS Over Time

Year	Number of variables	Changes	Person nonresponse rate
1992–93	86		N/A
1995–96	69		14.8; 15.6; 13.1
1998–99	73		13.0; 15.4; 18.0
2000	27	An abbreviated version of the TUS-CPS and consisted of several questions measuring basic tobacco use prevalence (cigarettes, cigars, pipes, chewing tobacco, and snuff)	12.0; 12.9
2001–02	75		18.4; 17.7; 16.3
2003	240	The 2003 Tobacco Use Special Cessation Supplement (TUSCS) had several unique topics covering: • type of cigarette usually smoked (menthol, lights); • switching to lighter cigarettes; • level of nicotine dependence; • products, treatments and methods used to quit cigarette and/or other tobacco product use; • cessation behavior for "other" non-cigarette tobacco products (cigars, pipes, chewing tobacco and snuff); • use of new harm reduction products; • specific guidance from health professionals; and • cost of last pack/carton of cigarettes purchased and in which state purchased.	16.4; 18.3; 16.8
2006–07	168	A core TUS was fielded that combined some of the new features of the 2003 TUSCS-CPS with the general 2001–02 TUS. Topics that had not previously been fielded included: • cost and purchase of "single" cigarettes; • smoking consumption about 12 months ago; • awareness and use of "quitlines" and advising family and friends to quit smoking; • use of "Marlboro Ultrasmooth", a new test-marketed tobacco product; • asking about other non-cigarette tobacco products separately rather than combined; and • asking about attitudes toward clean indoor air policies for children's outdoor sports fields and playgrounds, and indoor concert venues.	19.3; 18.3; 14.8*
2010–11	323	The TUS-CPS included more detailed questions than previous survey cycles on: • menthol cigarette use; • recent quit attempts; • recent quitting; • treatment and other methods used to quit; • emerging products (dissolvables and E-cigarettes); and • attitudes toward clean indoor air policies for casinos and cars.	17.8; 17.9; 18.4*

Source: Author's counting, codebooks for each of the Tobacco Use Supplement to the Current Population Survey and http://appliedresearch.cancer.gov/studies/tus-cps/questionnaire.html. The person nonreponse rates are listed for each month of the TUS-CPS. * The rates for 2006–07 and 2010–11 are for those at least 18 years old.

Table 4 Marginal Effects of Smoking in Probit Regression of Matching between the First Rotation Group in the TUS-CPS and the Subsequent Basic CPS

Dependent variable: Successful matching

Years	(1) MIS 2	(2) MIS 3	(3) MIS 4	(4) MIS 5	(5) MIS 6	(6) MIS 7	(7) MIS 8	Sample size
1992–93	-0.000	-0.009*	-0.014**	-0.027***	-0.021***	-0.028***	-0.025***	34,325
	(0.005)	(0.005)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)	
1995–96	-0.002	-0.007	-0.008	-0.036***	-0.037***	-0.036***	-0.037***	29,754
	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)	(0.006)	
1998–99	-0.004	-0.014***	-0.010**	-0.038***	-0.033***	-0.033***	-0.034***	28,823
	(0.004)	(0.004)	(0.005)	(0.007)	(0.008)	(0.008)	(0.008)	
2000	0.002	-0.007	-0.002	-0.010	-0.011	-0.023**	-0.021**	19,423
	(0.005)	(0.006)	(0.006)	(0.010)	(0.009)	(0.009)	(0.009)	
2001–02	-0.004	-0.012**	-0.018***	-0.032***	-0.035***	-0.035***	-0.036***	33,308
	(0.004)	(0.005)	(0.006)	(0.007)	(0.008)	(0.008)	(0.008)	
2003	0.002	-0.000	-0.009*	-0.031***	-0.029***	-0.030***	-0.030***	32,733
	(0.004)	(0.005)	(0.005)	(0.007)	(0.008)	(0.008)	(0.007)	
2006–07	-0.010**	-0.010*	-0.011**	-0.026***	-0.022***	-0.023***	-0.026***	32,293
	(0.004)	(0.005)	(0.005)	(0.008)	(0.008)	(0.007)	(0.008)	
2010–11	-0.008*	-0.013**	-0.019***	-0.037***	-0.040***	-0.038***	-0.044***	31,874
	(0.004)	(0.006)	(0.005)	(0.008)	(0.008)	(0.008)	(0.008)	

Note: Standard errors in parentheses. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
The following control variables are included: three dummies for age categories (18 to 24, 25 to 44, 45 to 64; the reference group is age 65 or older); a female dummy; five dummies for race/ethnicity (Black, Hispanic, American Indian/Alaskan Native, Asian/Pacific Islander, and other; the reference group is White); three dummies for education (high school, some college, and college or more; the reference group is less than high school); two dummies for employment status (unemployed and not in labor force; the reference group is employed); three dummies for marital status (married, widowed, and divorced/separated; the reference group is never married); dummies for family income levels, including family income missing; a dummy for home owner; two dummies for metropolitan areas (non metropolitan area and not identified; the reference group is metropolitan area); three region dummies; dummies for TUS-CPS month in each period; a dummy for self-response (the reference group is proxy response); a dummy for personal interview (the reference group is telephone interview); and a dummy for availability of a telephone in the house.

Table 5 Marginal Effects of Smoking in Probit Regression of Matching between the First Rotation Groups in the January and May 1999 and February 2002 TUS-CPS and Fifth Rotation Groups in the January and May 2000 and February 2003 Basic CPS and TUS-CPS

Dependent variable: Successful matching

	(1) Basic CPS	(2) TUS-CPS	Sample size
January and May 1999	-0.0309*** (0.0100)	-0.0312*** (0.0118)	19,058
February 2002	-0.0547*** (0.0115)	-0.0684*** (0.0130)	11,027

Note: Standard errors in parentheses. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
The following control variables are included: three dummies for age categories (18 to 24, 25 to 44, 45 to 64; the reference group is age 65 or older); a female dummy; five dummies for race/ethnicity (Black, Hispanic, American Indian/Alaskan Native, Asian/Pacific Islander, and other; the reference group is White); three dummies for education (high school, some college, and college or more; the reference group is less than high school); two dummies for employment status (unemployed and not in labor force; the reference group is employed); three dummies for marital status (married, widowed, and divorced/separated; the reference group is never married); dummies for family income levels, including family income missing; a dummy for home owner; two dummies for metropolitan areas (non metropolitan area and not identified; the reference group is metropolitan area); three region dummies; dummies for TUS-CPS month in each period; a dummy for self-response (the reference group is proxy response); a dummy for personal interview (the reference group is telephone interview); and a dummy for availability of a telephone in the house.

Table 6 Panel Conditioning: Marginal Effects of Rotation Group 1 in Probit Regression on Smoking, TUS-CPS Respondents Matched Across Their First and Second Months in Sample

Dependent variable: Current Smoker

Panel A No Control

	(1) 1992–93	(2) 1995–96	(3) 1998–99	(4) 2000	(5) 2001–02	(6) 2003	(7) 2006–07	(8) 2010–11
Rotation group 1	0.014**	0.007	0.010**	0.014**	0.006	0.017***	0.017***	0.019***
	(0.005)	(0.007)	(0.005)	(0.006)	(0.005)	(0.005)	(0.004)	(0.005)
Observations	69,760	35,927	54,065	35,969	59,384	60,294	58,766	58,055

Panel B Full Control

	(1) 1992–93	(2) 1995–96	(3) 1998–99	(4) 2000	(5) 2001–02	(6) 2003	(7) 2006–07	(8) 2010–11
Rotation group 1	0.003	0.004	-0.001	0.006	-0.002	0.014**	0.006	0.010*
	(0.006)	(0.008)	(0.006)	(0.008)	(0.006)	(0.006)	(0.005)	(0.005)
Observations	69,760	35,927	54,065	35,969	59,384	60,294	58,766	58,055

Note: Standard errors in parentheses. The results are weighted using the Tobacco Use Supplement to the Current Population Survey nonresponse weight (PWNRWGT) and standard errors have been estimated using the balanced repeated replication method. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
The following control variables are included in the results presented in Panel B: three dummies for age categories (18 to 24, 25 to 44, 45 to 64; the reference group is age 65 or older); a female dummy; five dummies for race/ethnicity (Black, Hispanic, American Indian/Alaskan Native, Asian/Pacific Islander, and other; the reference group is White); three dummies for education (high school, some college, and college or more; the reference group is less than high school); two dummies for employment status (unemployed and not in labor force; the reference group is employed); three dummies for marital status (married, widowed, and divorced/separated; the reference group is never married); dummies for family income levels, including family income missing; a dummy for home owner; two dummies for metropolitan areas (non metropolitan area and not identified; the reference group is metropolitan area); three region dummies; dummies for TUS-CPS month in each period; a dummy for self-response (the reference group is proxy response); and a dummy for personal interview (the reference group is telephone interview).